SmartSPIN

Energy efficiency in the commercial rented sector and verification of rebound effect after PV system installation in shopping centre in Spain

Luciano De Tommasi

Workshop: Fostering changes in energy consumption: a pathway to demand reduction

University of Padova

26th October 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

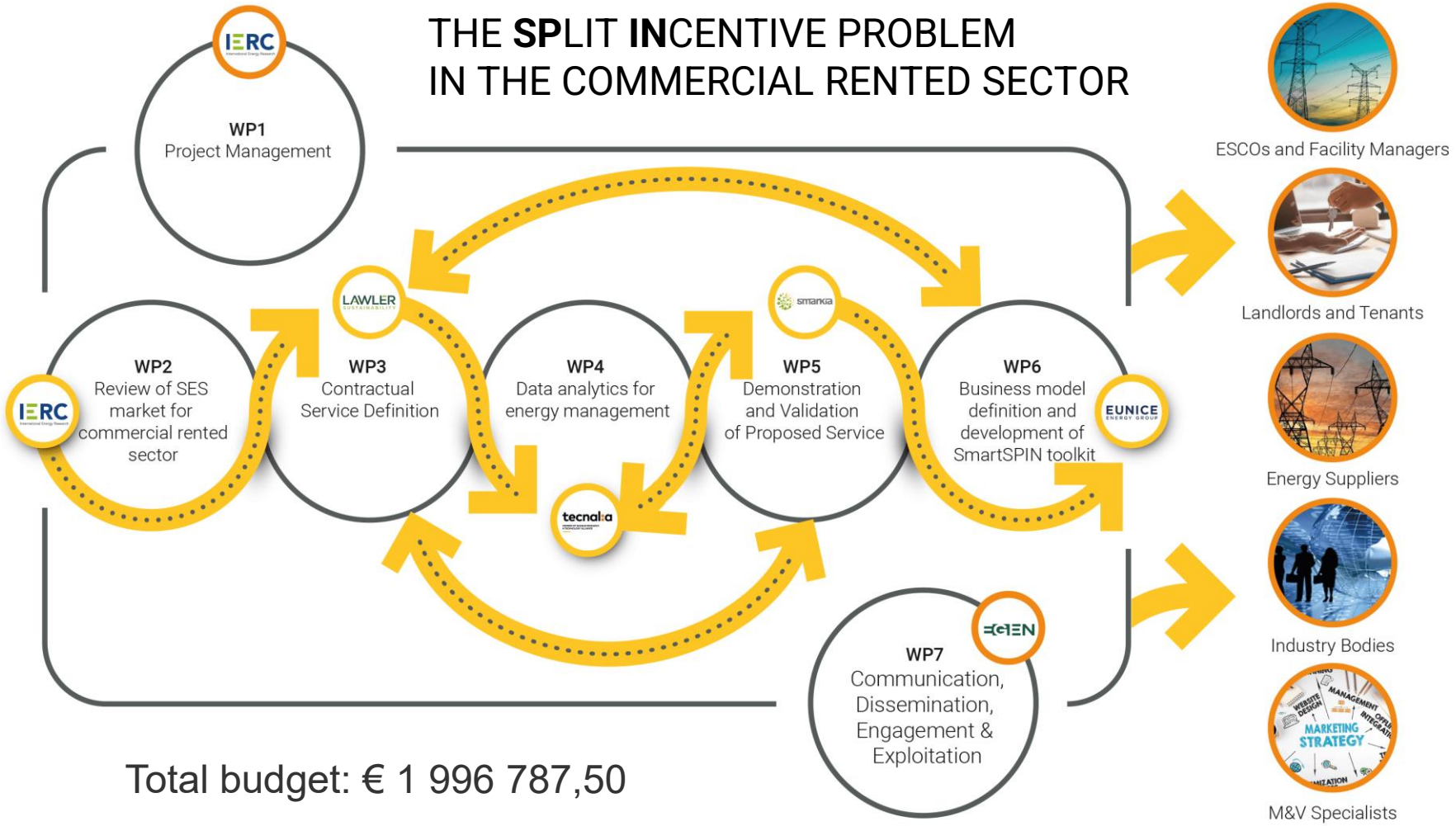
Outline

- Introduction to the SmartSPIN project
- Business model and revenue streams
- SmartSPIN service and its validation
- Impacts
- Rebound effect at La Gavia Shopping Centre
- Modelling of Rebound Effect
- Considerations on the optimal share of energy savings between building owner and renters
- Conclusions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 10133744.

SmartSPIN Project

SMART ENERGY SERVICES TO SOLVE
THE **SP**LIT **IN**CENTIVE PROBLEM
IN THE COMMERCIAL RENTED SECTOR



Total budget: € 1 996 787,50

Partners:

IERC International Energy Research
LAWLER SUSTAINABILITY
tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
HEBES
EUNICE ENERGY GROUP
EGEN

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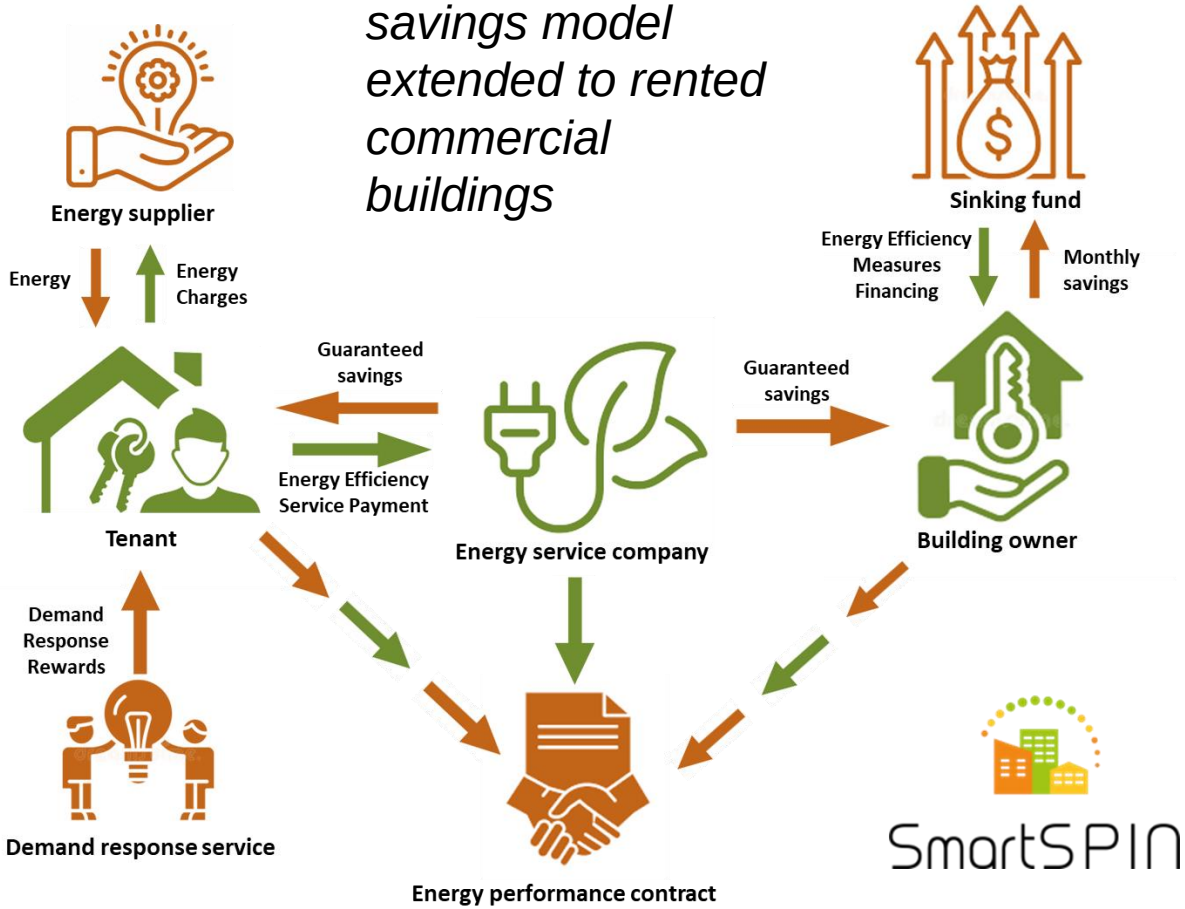
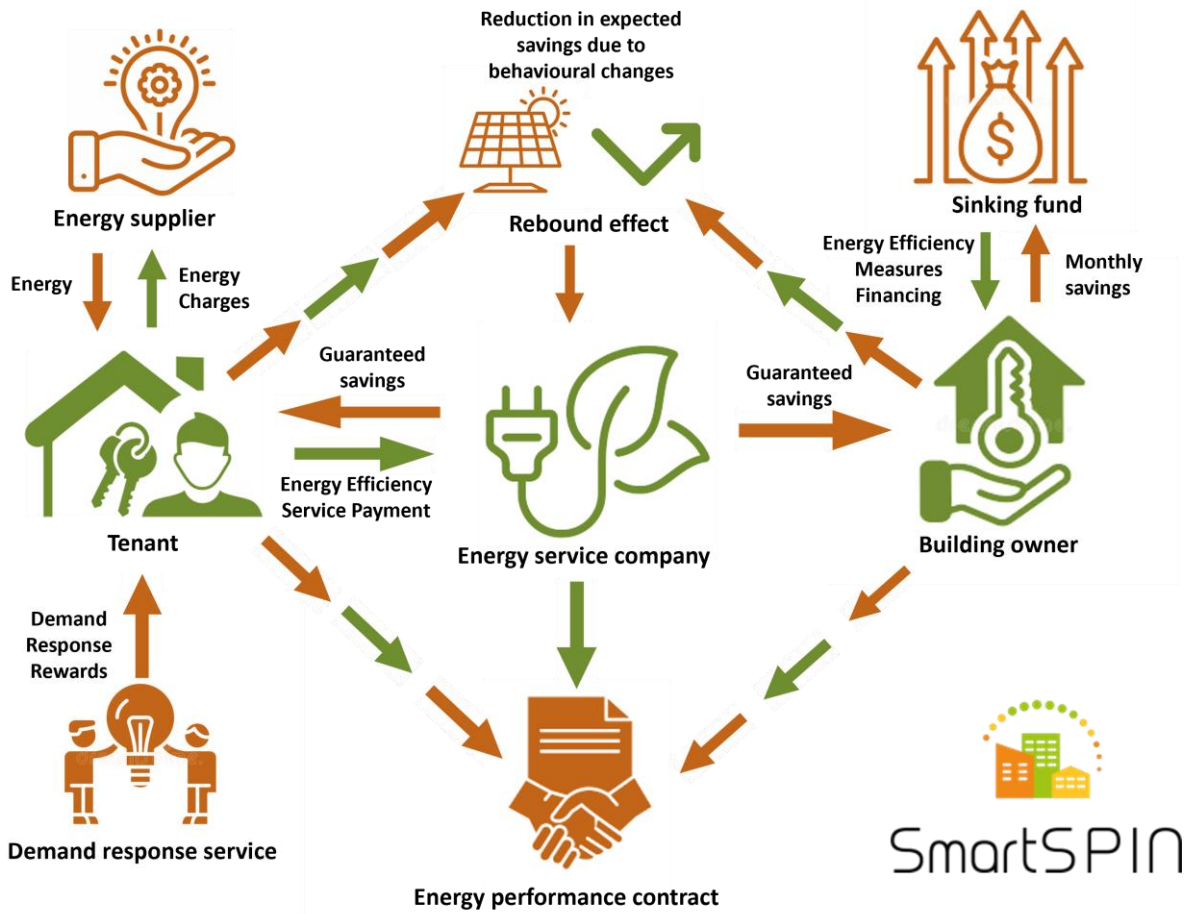
Business model & revenue streams

Guaranteed savings model extended to rented commercial buildings



Guaranteed savings model including rebound effect



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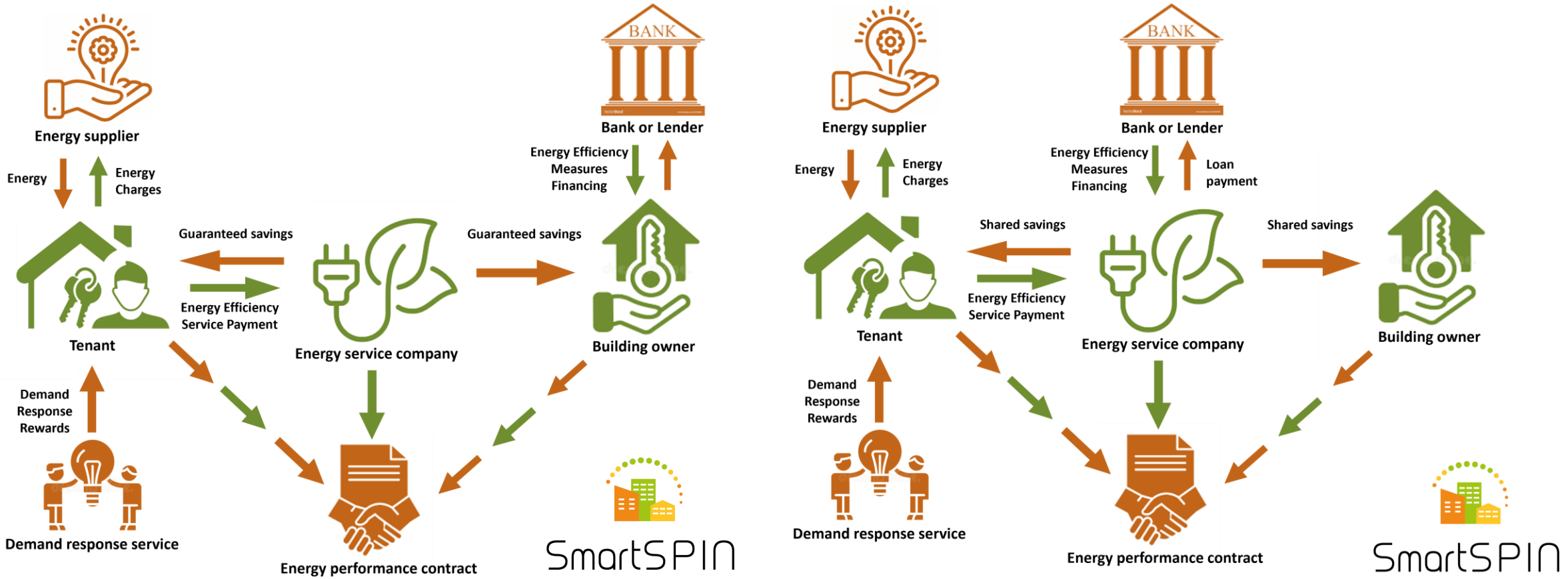
Business model & revenue streams



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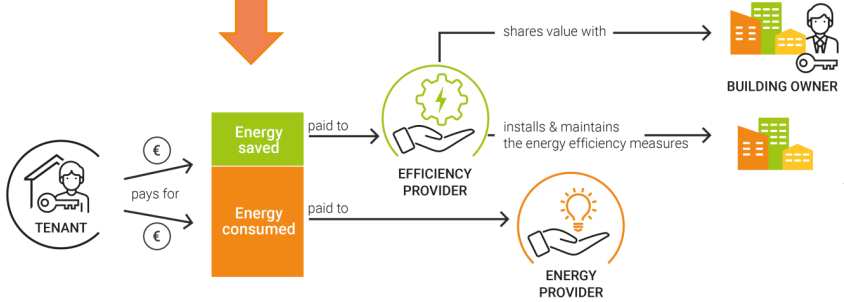
SmartSPIN service and its validation

Task 7.1 – Further interviews or discussions with stakeholders

D3.5 Contractual and tariff templates

Parts of the service deployed in each pilot site, and related arrangements (e.g., agreements between landlord / tenant / service provider).

Task 5.4 – Impact of gamification on tenant engagement



Task 5.5 – Validation of SmartSPIN service

Task 1.6 Evaluation and monitoring of the performance indicators

T4.5 User engagement through data - platform integration and visualisation (Front-end)

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Impacts for Spain

Project Performance Indicator	Old Numbers	New Numbers
Renewable Electricity Generation (GWh/year)	0	1.16
Primary Energy Saving triggered by the project (GWh/year)	1.82	3.99
Reduction in GHG emission triggered by the project (tonnes CO2eq/year)	283	617
Investment in sustainable energy triggered by the project (€M)	6.17	XXX

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Impacts total

Project Performance Indicator	Old Impact Numbers	New Impact Numbers
Floor Area (m^2)	179,309	166,566
Baseline Electricity Consumption (GWh/year)	11.54	10.05
Baseline Natural Gas Consumption (GWh/year)	3.93	2.32
Renewable Electricity Generation (GWh/year)	1.10	1.36
Primary Energy Saving triggered by the project (GWh/year)	4.53	4.72
Reduction in GHG emission triggered by the project (tonnes CO2eq/year)	941	812
Investment in sustainable energy triggered by the project (€M)	8.27	7.38

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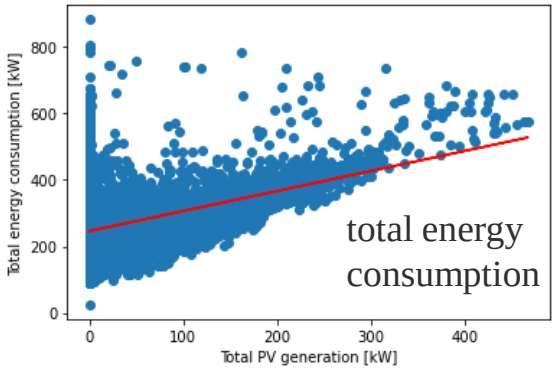
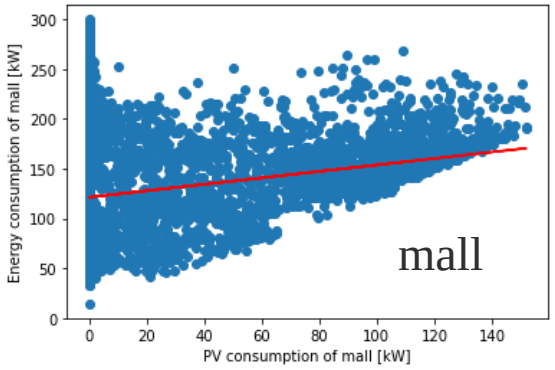
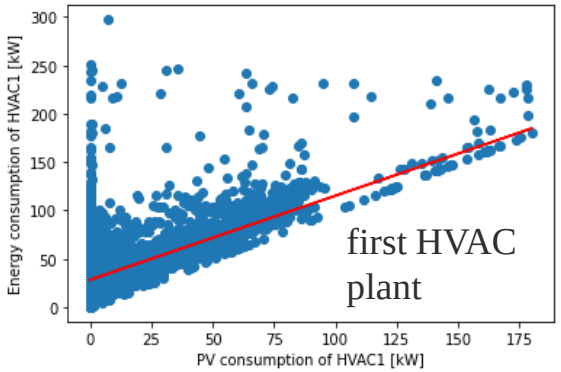
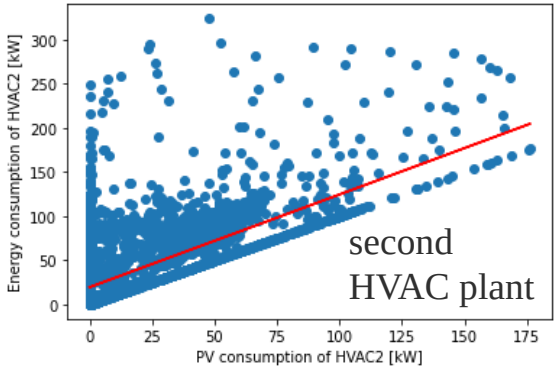
Rebound effect at La Gavia shopping centre (Madrid)

- A PV-system was installed in **La Gavia shopping centre**, located in Ensanche de Vallecas district, 11 km from the city centre of Madrid.
- La Gavia includes 175 retail shops.
- Data collection started on September 1st, 2022, with hourly resolution.









Energy consumption cluster	Estimated rebound effect
Total energy consumption	60.25%
Mall	32.5 %
HVAC 1	87.11 %
HVAC 2	105.01 %

Model including lagged PV electricity generation:

$$E_{C,Tot}^{(t)} = 214.2001 - 1.2093 \cdot E_{PV,Tot}^{(t-4)} - 0.6694 \cdot E_{PV,Tot}^{(t-3)} + 0.3958 \cdot E_{PV,Tot}^{(t-2)} - 1.0070 \cdot E_{PV,Tot}^{(t-1)} + 1.1766 \cdot E_{PV,Tot}^{(t)}$$

root mean squared error of 112.1167 versus 122.8736 of instantaneous effect model

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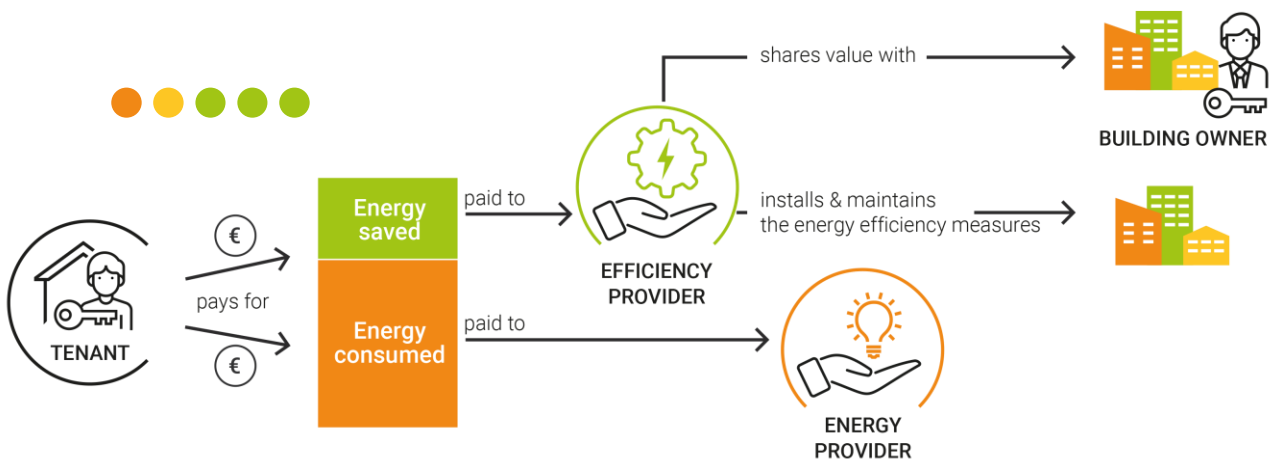
Modelling of rebound effect



$$b = \frac{\Phi}{1 - e^{-100/\rho}} \qquad a = 1 - b \qquad Re = a + b \cdot e^{-(200 \cdot \theta - 100)/\rho}$$

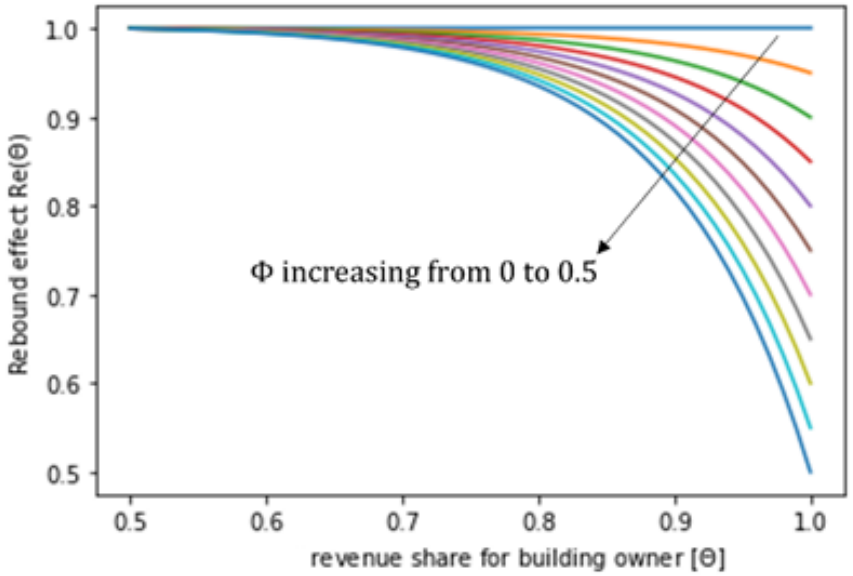
$$Q(t) = f(t) Re(\theta) K(t) \quad t = 1, \ldots, N$$

$$R(t) = Q(t) P_E(t) \quad t = 1, 2, \ldots, N$$

$$R_O(t) = \begin{cases} 0 & t = 0 \\ \theta\left(\alpha G + \max\left[0, \beta(R(t) - G)\right]\right) & t = 1, 2, \ldots, n \\ R(t) - R_R & t = n+1, n+2, \ldots, N \end{cases}$$

$$NPV_O = \sum_{t=0}^{N} \frac{R_O(t) - I_{OM}(t)}{(1 + r_O)^t}$$

- **Q:** What does determine the optimal share of energy savings between building owner and tenant?
- **A:** The revenue share for the building owner θ and renters 1 – θ
- θ = 1 the owner takes all the savings and rebound effect is maximum



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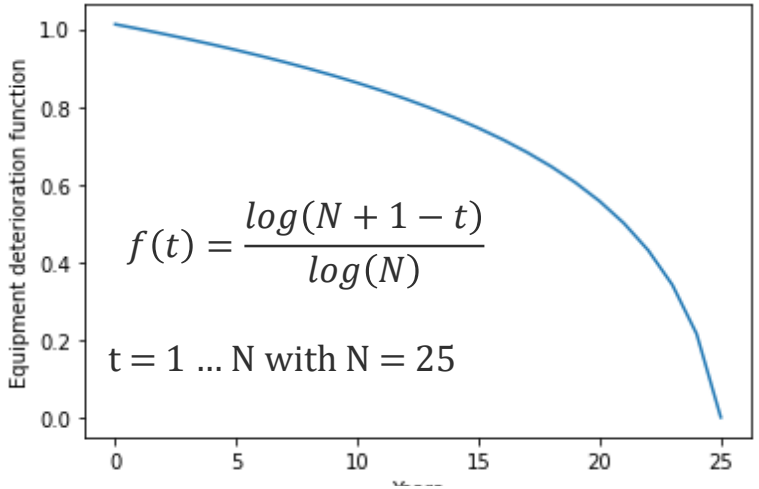
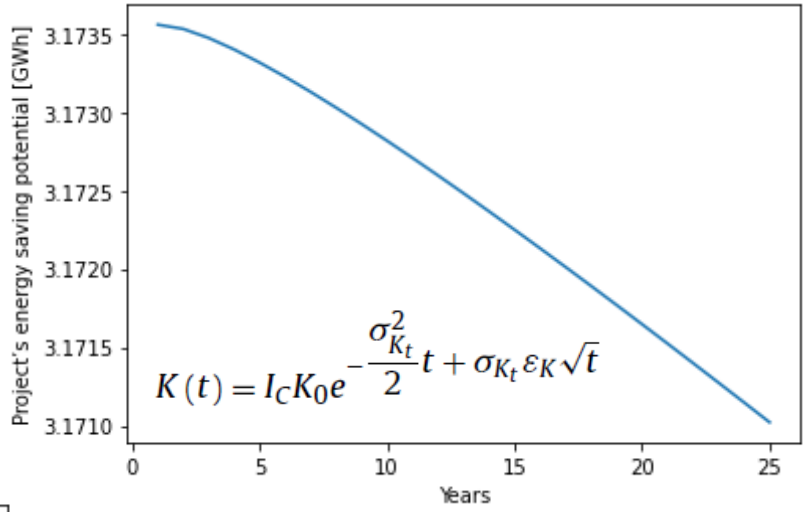
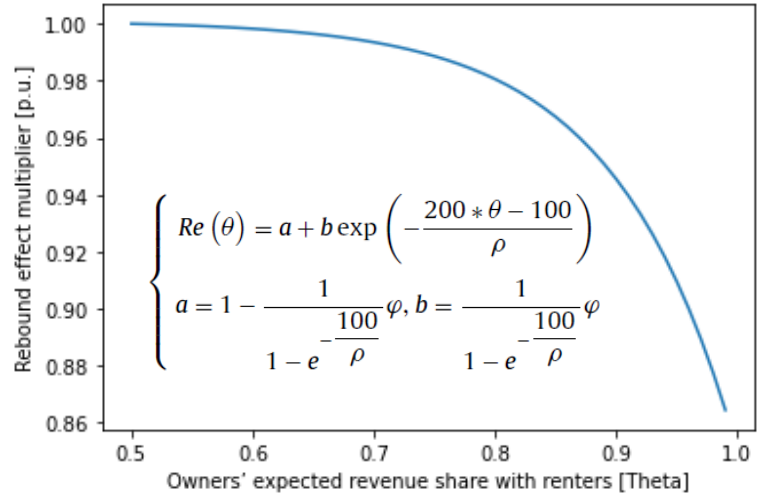
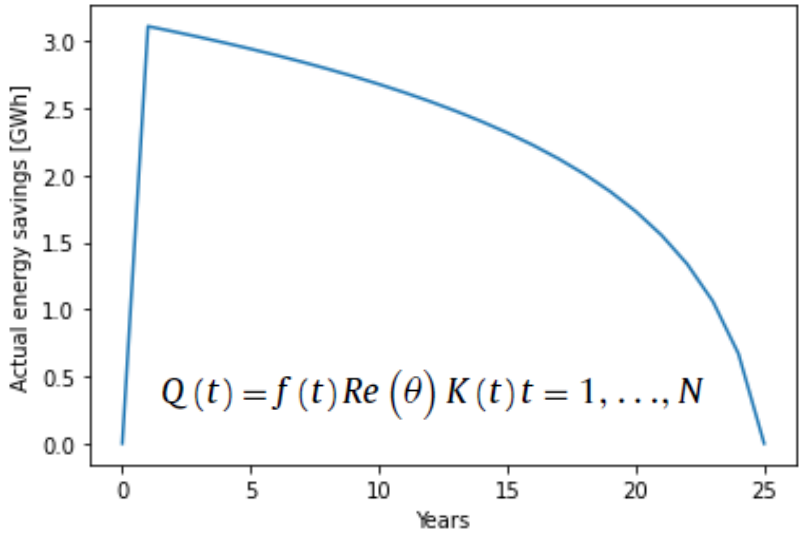
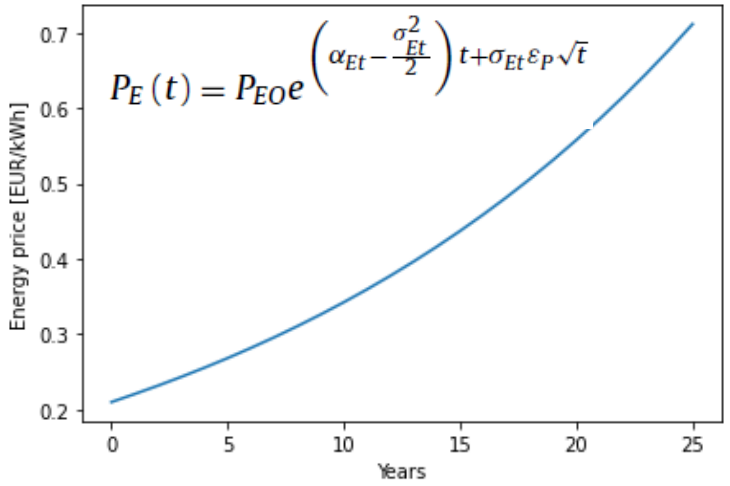
Revenue stream from energy savings

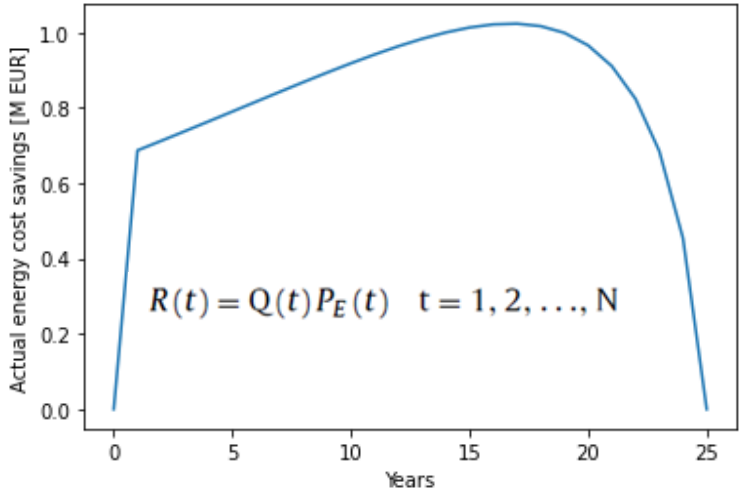












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Optimal revenue share for building owner

Parameters used in next two slides:

1 Volatility of the O&M cost coefficient: $\boldsymbol{\sigma_H}$ = 0.25
2 Volatility of the energy saving amount coefficient: $\boldsymbol{\sigma_K}$ = 0.01
3 Energy price drift effect: $\boldsymbol{\alpha_E}$ = 0.0523
4 Energy price volatility effect: $\boldsymbol{\sigma_E}$ = 0.0856
5 O&M trend index: $\boldsymbol{\delta}$ = 1.025
6 Initial value of the O&M cost coefficient: $\boldsymbol{H_0}$ = 0.0036
7 Initial value of the energy saving amount coefficient: $\boldsymbol{K_0}$ = 0.3
8 Initial value of the energy price: $\boldsymbol{PE_0}$ = 0.24
9 Economic lifetime of the energy efficiency system: **N** = 25
10 Capital cost of the energy efficiency investment: $\boldsymbol{I_C}$ = 6170000 (*invested by ESCO*)

11 Annual energy cost savings guarantee: **G** = 431900
12 Owners' expected revenue share within the guarantee: $\boldsymbol{\alpha}$ = 1
13 Owners' excess revenue share beyond the guarantee: $\boldsymbol{\beta}$ = 0.2
14 Owners' expected rate of return: $\boldsymbol{r_0}$ = 0.031
15 Renters' expected rate of return: $\boldsymbol{r_R}$= 0.031
16 ESCOs' expected rate of return: $\boldsymbol{r_E}$ = 0.06
17 Owners' expected revenue share with renters: $\boldsymbol{\theta}$ = variable
18 Maximum renters' rebound effect: $\boldsymbol{\Phi}$ = variable
19 Risk attitude of renters: $\boldsymbol{\rho}$ = −20

Reference:

Lu, Y., Zhang, N., & Chen, J. (2017). A behavior-based decision-making model for energy performance contracting in building retrofit. *Energy and Buildings*, *156*, 315-326.

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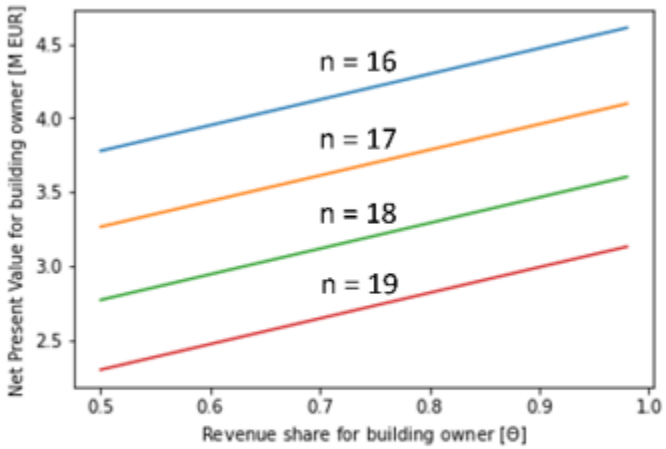
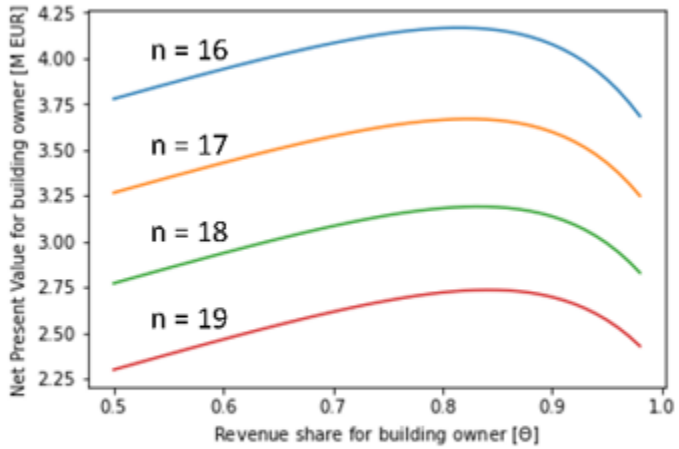
Optimal revenue share for building owner

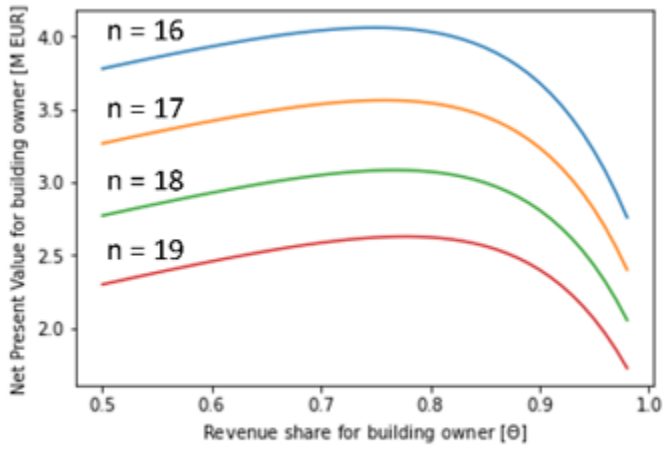
- We build on Lu, Zhang & Chen (2017) to gain further insights on how the renters' rebound effect influences the optimal revenue shares for the building owner θ_{opt} and renters 1 - θ_{opt}
- The building owner's Net Present Value depends on the revenue share for the building owner (agreed with renters) and on the contract duration n.
- The optimal revenue share for building owner θ_{opt} is the revenue share that maximizes building owner's Net Present Value. θ_{opt} depends on the rebound effect Φ



$\Phi = 0$



$\Phi = 0.2$



$\Phi = 0.4$

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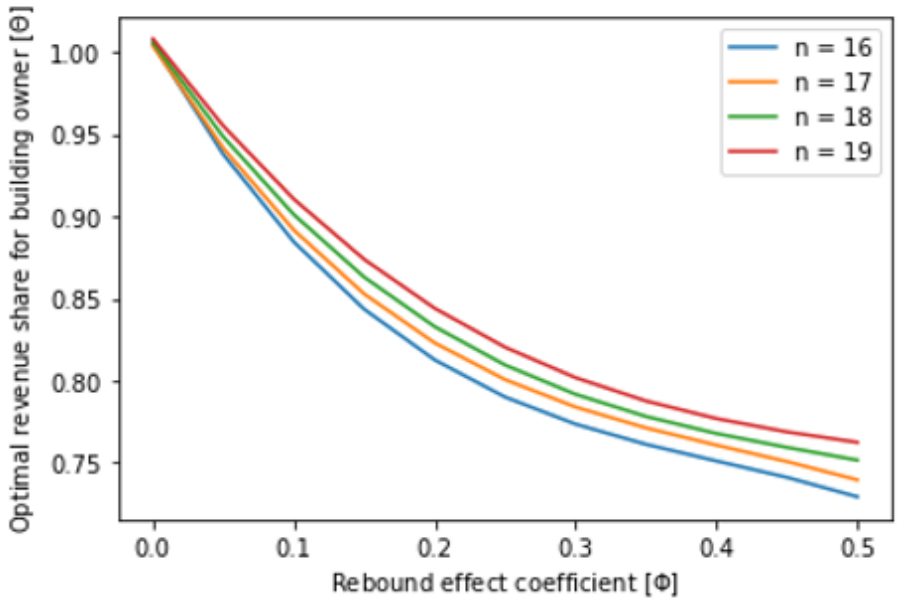
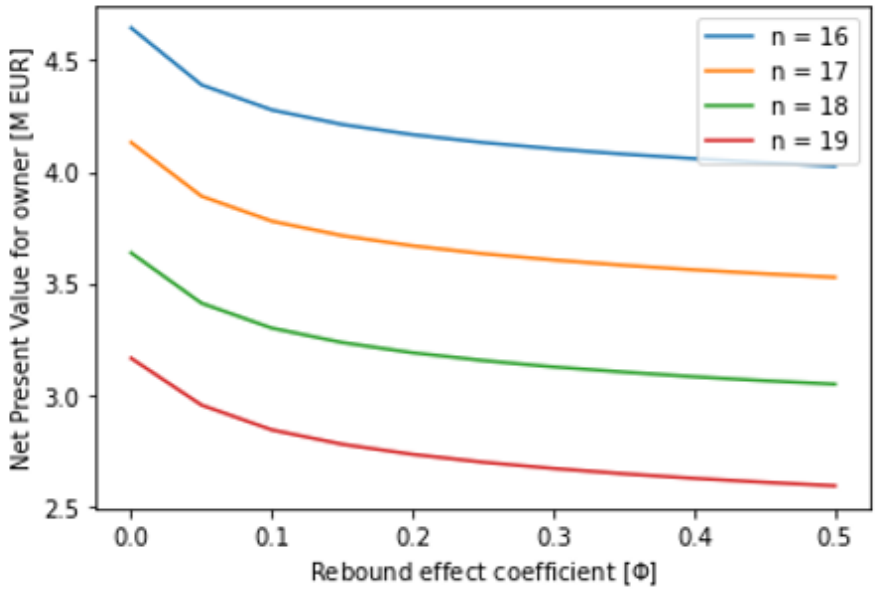
Optimal revenue share for building owner

- The optimal revenue share for building owner θ_{opt} and building owner's Net Present Value NPV_{opt} depend on the rebound effect $\boldsymbol{\Phi}$
- As the rebound effect $\boldsymbol{\Phi}$ increases θ_{opt} will decrease as the building owner will prefer to share more savings with renters to incentivise them to consume less energy.





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Conclusions

- SmartSPIN is developing a business model applicable to the commercial rented sector where energy savings from an energy efficiency project are divided between building owner, renters and Energy service company.
- Bargaining and contractual agreements between parties need to be facilitated through a model that determines the optimal shares of savings between building owner and renters.
- Energy Service Companies and building owners must be made aware of the fact that rebound effect may reduce expected energy savings.
- Sharing an appropriate fraction of energy savings $1 - \theta$ with renters may incentivise energy efficient behaviours and may even increase revenue streams for building owners.
- Data collected from the field about PV-generation and energy consumption at La Gavia Shopping Centre was analysed to determine rebound effect.
- Further work: measured data will be used to extend a state-of-the art model for rebound effect found in the literature which does assumptions on the coefficients of the model.

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Backup

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SmartSPIN Tookit

Business model CANVAS

KEY PARTNERS

> Main Material/Components suppliers
- Smart Devices
- RES & Storage components and infrastructure
- E-Mobility infrastructure
- Smart Monitoring & Management Platform
> Contractors/Technical support network.
>EaaS provider/ Market Facilitators
>ESCOS
> Project financier
> Energy Performance Contracting facilitator
> Energy efficiency consultant

KEY ACTIVITIES

> Energy management data collection & consulting for energy management optimization
> Development of sizing tools and user-friendly applications
> Activities to define customer's needs and requirements for the integration of the solution/toolkit
> Selection of one or more packages of energy conservation measures (that form the solution)
> Definition of a staggered plan to implement energy conservation measures
> Measure & verify energy savings
> Run an Energy Performance Contract
>Implemention of suggested/selected energy saving measures
> Awareness raising and customer engagement
> Training and behavioural change of users (TBD)
> Dissemination campaign (TBD)

KEY RESOURCES

HUMAN:
> Partners Technicians/Contractors
>Energy Experts/consultants
PHYSICAL/MATERIALS:
> Supply chain (orders, procurment, warehouse)
INTELLECTUAL
>Energy efficiency improvement Equiments/instruments
>
Capital (National or EU funding schemes)
TECHNOLOGY
> energy efficient equipment and measures
> building diagnostics tool
> technologies for smart controls in building
>Gamification App

VALUE PROPOSITION

> The SmartSPIN Toolkit is an all-in-one solution for solving the split-incentive issue in the Commercial Rented sector offering along with significant enegy optimization techniques, transparent methods for electricity billings in a more democratized way.
> Standard & flexible/adaptable solutions.
> Accessibility in remote support and monitoring
> User Friendly Dashboard/ User Friendly Template >
Smart energy management and control system
>Dynamic tariff for electricity consumption (TBD)
>Electricity Prices Forecasting platform
> Sharing the benefits of energy efficiency and the energy savings between the parties in a fair manner
> Incentivize both tenants and landlords in engaging with a EaaS provider to improve energy efficiency of commercial buildings.
> Maximize the investments in energy efficiency in the commercial rented sector.
>Improved thermal comfort of the occupiers
>Green image of the building with reduced carbon footprint and better compitetive opportunity in the market

CUSTOMER RELATIONSHIP

> Face customer as partner. Seek dedicated solutions together.
> Co-Creation for tailor made solutions
> Flexible contracts
> Green Lease
> On bill financing
> Tri-partite Energy Performance Contracting

CHANNELS

> B2B & B2C contacts
> Partnerships (Contractors, Technicians)
> Energy Service and Utility Companies
> Public tenders
> Website, Sales & Marketing
> Registers of Energy Performance Contracting facilitators
> Associations of ESCOs
>Social media, conferences, workshops
>Local/National authorities
>Regulation/Ministry of Energy

CUSTOMER SEGMENT

- Building owners (commercial or business buildings, Malls, industrial plants)
- Facility Managers & Companies - Landlord -Building Management Companies
- Energy users (businesses, industries)
- Tenants of commercial buildings and facilities

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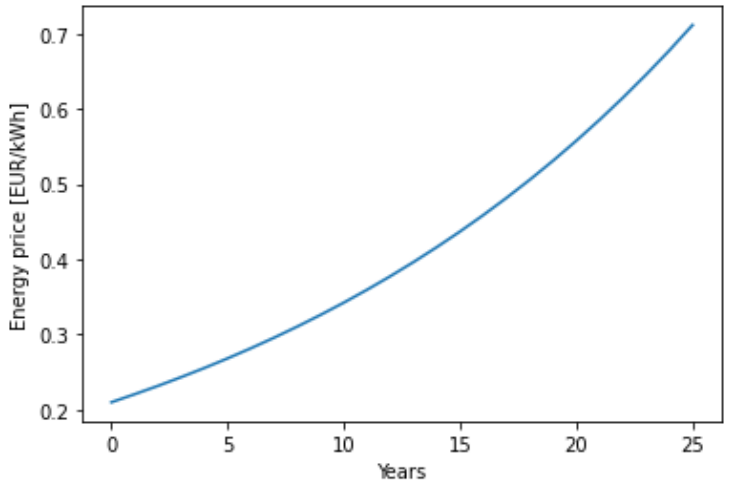
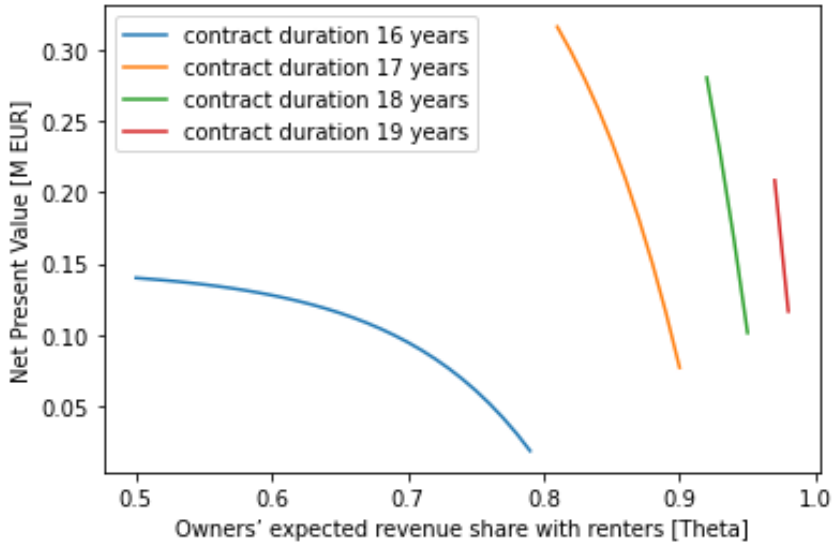
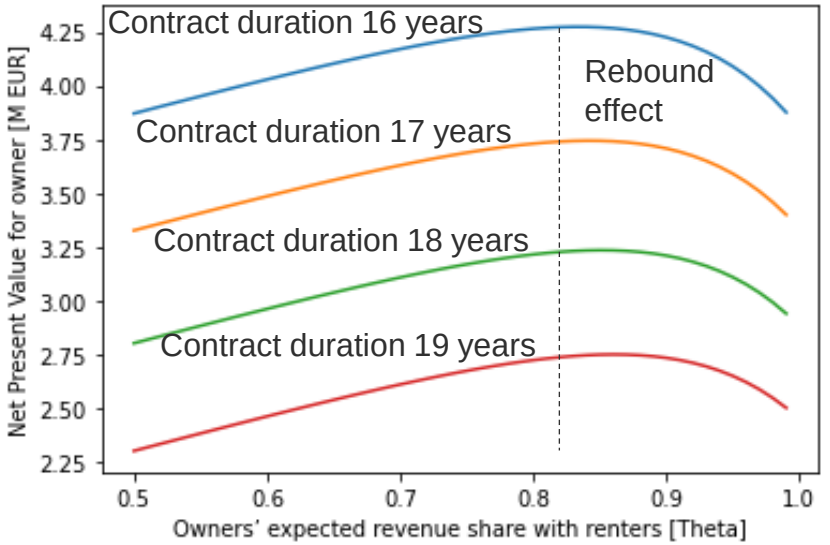
Validation of SmartSPIN service

Simulation model for optimal revenue share between ESCO, landlord and tenant.

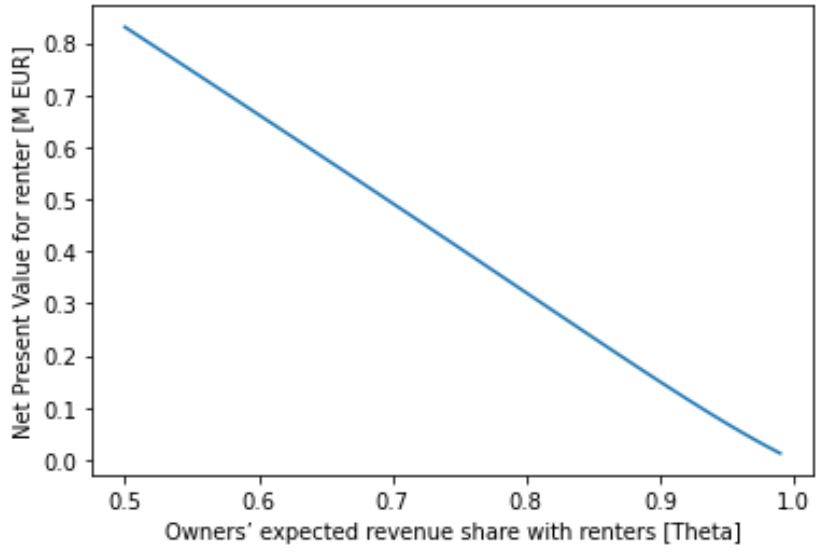
Scenario 1 – ESCO is investing







$$n^* = arg\max(NPV_0), subjecttoNPV_E \geq 0$$



- Reference simulation model established to determine optimal revenue share between owners and renters under assumption of performance guarantee from energy efficiency provider (Lua, Zhanga, Chen, 2017).
- Investment 7.38 M EUR
- Service provider guarantees 7% of investment energy savings per year
- Optimal share: 80% savings for landlord, 20% for tenant

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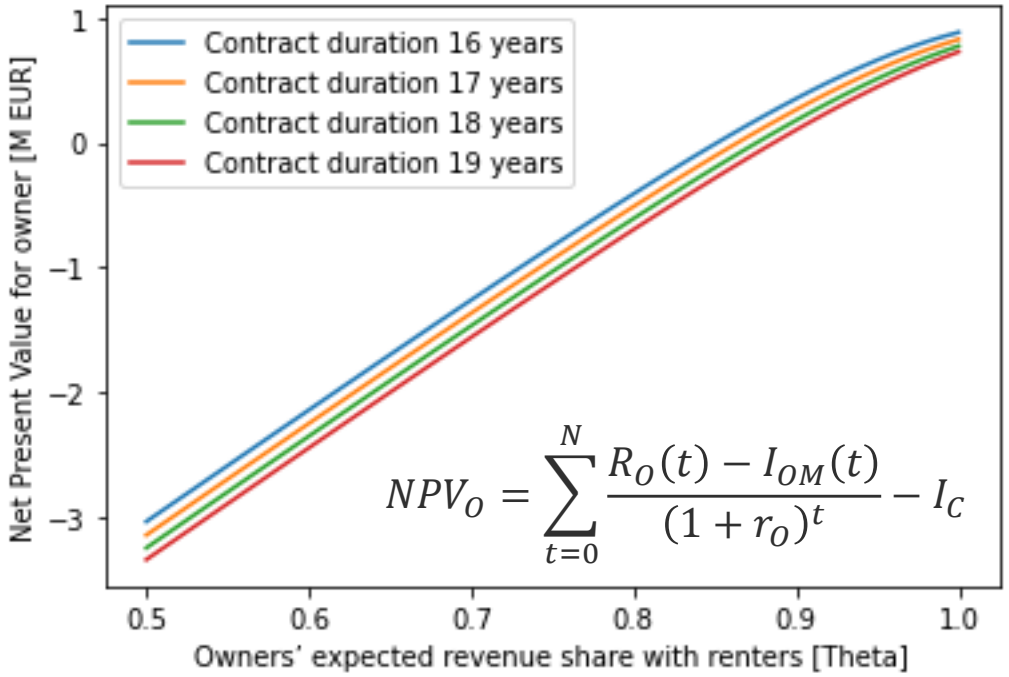
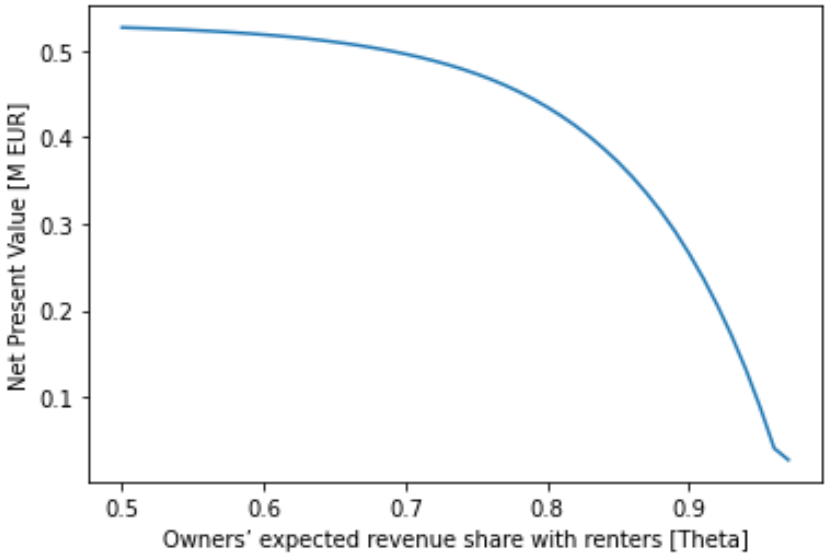
Validation of SmartSPIN service

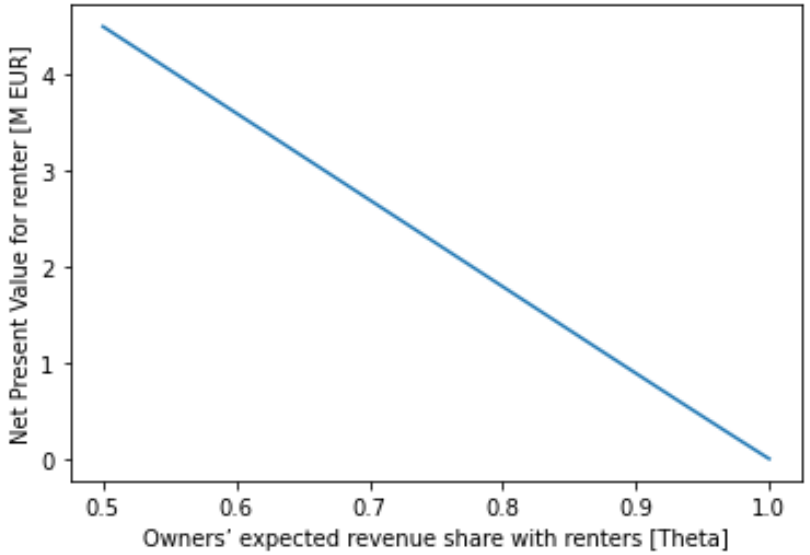
Simulation model for optimal revenue share between ESCO, landlord and tenant.

- Scenario 2 – Landlord is investing





$$NPV_E = \sum_{t=0}^{n} \frac{R_E(t) - I_{OM}(t)}{(1+r_E)^t}$$



$$NPV_R = \sum_{t=1}^{N} \frac{R_R(t)}{(1+r_R)^t}$$

- If revenue share of the landlord is too low, then NPV becomes negative (landlord will not invest)
- Landlord will take up to 100% of the energy savings guaranteed by the service provider to maximise their NPV

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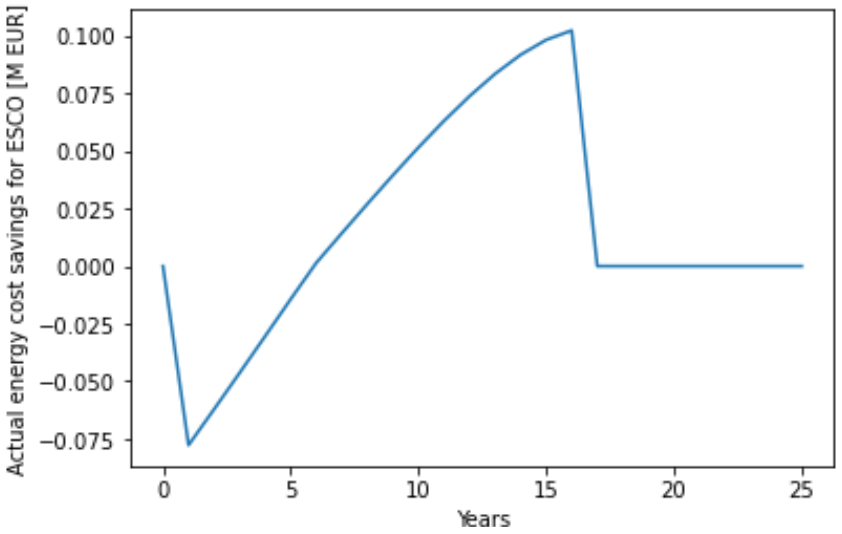
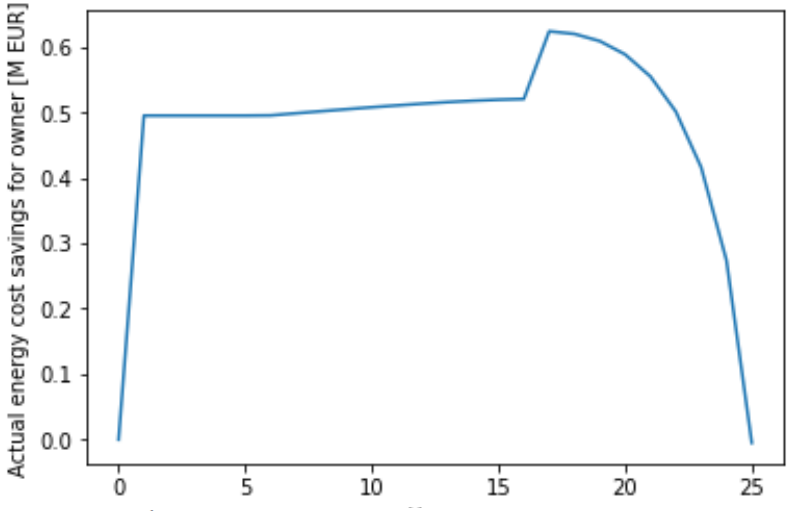
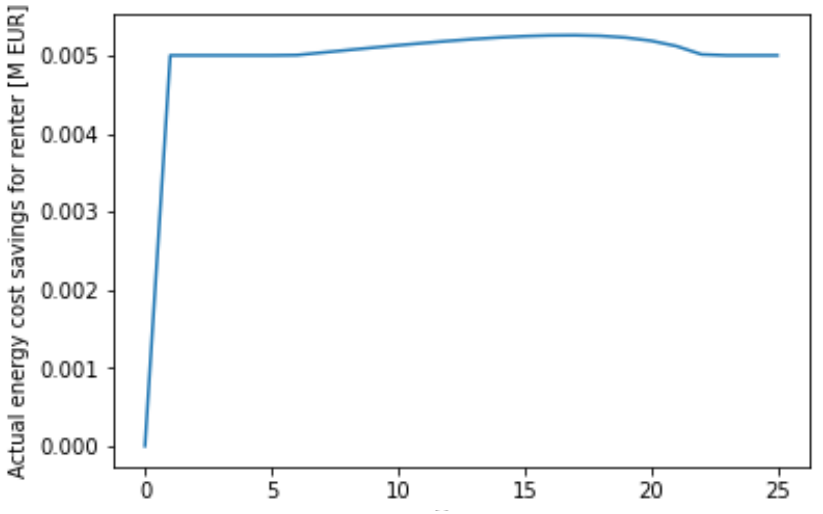
Validation of SmartSPIN service

Simulation model for optimal revenue share between ESCO, landlord and tenant.



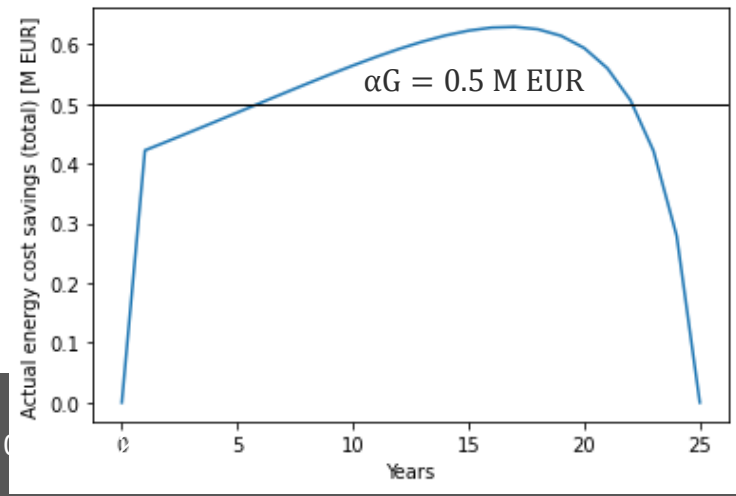


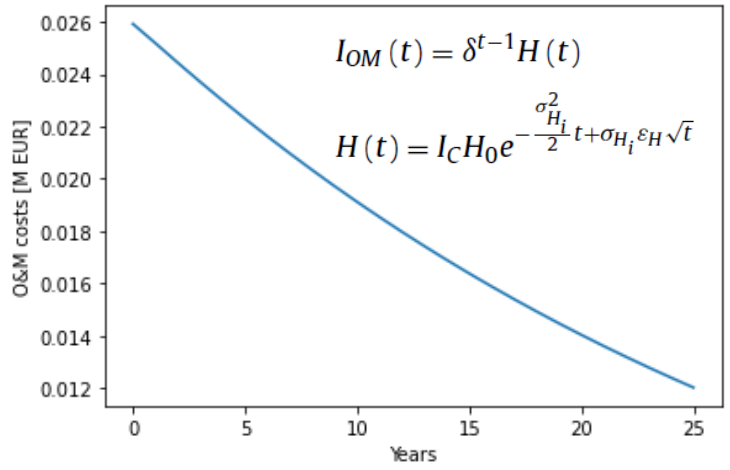


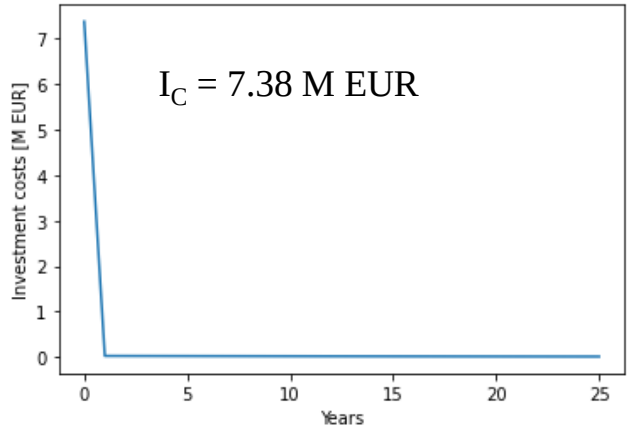
$$R_E(t) = \begin{cases} 0 & t = 0 \\ R(t) - \alpha G - \max\left[0, \beta(R(t) - G)\right] & t = 1, 2, \ldots, n \\ 0 & t = n+1, n+2, \ldots, N \end{cases}$$

$$R_O(t) = \begin{cases} 0 & t = 0 \\ \theta\left(\alpha G + \max\left[0, \beta(R(t) - G)\right]\right) & t = 1, 2, \ldots, n \\ R(t) - R_R & t = n+1, n+2, \ldots, N \end{cases}$$

$$R_R(t) = \begin{cases} 0 & t = 0 \\ (1-\theta)\left(\alpha G + \max\left[0, \beta(R(t) - G)\right]\right) & t = 1, 2, \ldots, N \end{cases}$$







This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 10133744.

Validation of SmartSPIN service

Simulation model for optimal revenue share between ESCO, landlord and tenant. Legend of parameters.

Scenario 1

1 Volatility of the O&M cost coefficient: $\boldsymbol{\sigma_H}$ = 0.25
2 Volatility of the energy saving amount coefficient: $\boldsymbol{\sigma_K}$ = 0.01
3 Energy price drift effect: $\boldsymbol{\alpha_E}$ = 0.0523
4 Energy price volatility effect: $\boldsymbol{\sigma_E}$ = 0.0856
5 O&M trend index: $\boldsymbol{\delta}$ = 1.025
6 Initial value of the O&M cost coefficient: $\boldsymbol{H_0}$ = 0.0036
7 Initial value of the energy saving amount coefficient: $\boldsymbol{K_0}$ = 0.3
8 Initial value of the energy price: $\boldsymbol{PE_0}$ = 0.21
9 Economic lifetime of the energy efficiency system: **N** = 25
10 Capital cost of the energy efficiency investment: $\boldsymbol{I_C}$ = 7380000 (*invested by ESCO*)
11 Annual energy cost savings guarantee: **G** = 500000
12 Owners' expected revenue share within the guarantee: $\boldsymbol{\alpha}$ = 1
13 Owners' excess revenue share beyond the guarantee: $\boldsymbol{\beta}$ = 0.2
14 Owners' expected rate of return: $\boldsymbol{r_0}$ = 0.031
15 Renters' expected rate of return: $\boldsymbol{r_R}$= 0.031
16 ESCOs' expected rate of return: $\boldsymbol{r_E}$ = 0.06
17 Owners' expected revenue share with renters: $\boldsymbol{\theta}$ = variable
18 Maximum renters' rebound effect: $\boldsymbol{\vartheta}$ = 0.15
19 Risk attitude of renters: $\boldsymbol{\rho}$ = −20

Scenario 2

1 Volatility of the O&M cost coefficient: $\boldsymbol{\sigma_H}$ = 0.25
2 Volatility of the energy saving amount coefficient: $\boldsymbol{\sigma_K}$ = 0.01
3 Energy price drift effect: $\boldsymbol{\alpha_E}$ = 0.0523
4 Energy price volatility effect: $\boldsymbol{\sigma_E}$ = 0.0856
5 O&M trend index: $\boldsymbol{\delta}$ = 1.025
6 Initial value of the O&M cost coefficient: $\boldsymbol{H_0}$ = 0.0036
7 Initial value of the energy saving amount coefficient: $\boldsymbol{K_0}$ = 0.3
8 Initial value of the energy price: $\boldsymbol{PE_0}$ = 0.21
9 Economic lifetime of the energy efficiency system: **N** = 25
10 Capital cost of the energy efficiency investment: $\boldsymbol{I_C}$ = 7380000 (*invested by landlord*)
11 Annual energy cost savings guarantee: **G** = 500000
12 Owners' expected revenue share within the guarantee: $\boldsymbol{\alpha}$ = 1
13 Owners' excess revenue share beyond the guarantee: $\boldsymbol{\beta}$ = 0.2
14 Owners' expected rate of return: $\boldsymbol{r_0}$ = 0.031
15 Renters' expected rate of return: $\boldsymbol{r_R}$= 0.031
16 ESCOs' expected rate of return: $\boldsymbol{r_E}$ = 0.06
17 Owners' expected revenue share with renters: $\boldsymbol{\theta}$ = variable
18 Maximum renters' rebound effect: ϑ = 0.15
19 Risk attitude of renters: ρ = −20

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Ruchi Agrawal, Researcher, IERC

Thank you!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.